Framing Effects in Two-Sided Clock Auctions

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We test for a framing effect when sellers participate in clock auctions as competitors for their own offerings. Items 'lost' by sellers are sold to winning buyers, whereas items 'won' by sellers are withheld from the market. Theoretically this frame should not systematically affect seller behavior relative to an equivalent institution in which sellers do not bid on their own items. We evaluate each frame under two clock directions: ascending and descending prices. We find that the supply frame significantly affects strategic behavior from sellers and overall efficiency, while the clock direction affects buyers but not sellers.

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1. Introduction

In creating new institutions, auction theorists assume traders are rational and that equivalent rules applied to identical trading environments will produce consistent behavior. Contrary to this assumption, some experiments involving ‘frames’ have been shown to systematically affect decisions. A ‘frame’ refers to one’s “conception of the acts, outcomes, and contingencies associated with a particular choice” (Tversky and Kahneman 1981). In the experimental literature, an “institution” specifies the choices available to subjects and the rules for accepting and organizing messages (such as bids and asks) which the institution maps into allocations (Smith 1982). Frames have been shown to systematically affect outcomes depending on factors such as the instructions used by the experimenter (Hoffman, McCabe and Smith 1996), whether the decisions are framed as losses or gains (Kahneman and Tversky 1979), whether a trader is buying or selling (Knetsch 1989), and whether the allocation process itself is put in the context of a market rather than some other form of personal exchange (Hoffman, McCabe, Shachat and Smith 1994, Siegel and Fouraker 1960).

Some authors have proposed that one-sided auctions, in which the supply is fixed, could be made two-sided by allowing sellers to bid on their own offerings, supplying only those items ‘lost’ to competing buyers. If the seller ‘wins’ an item, it is simply withheld from exchange. Kwerel and Williams (2002, p. 3) suggest using this method to reorganize the ownership of FCC spectra licenses by “allowing [incumbent license holders] to bid on their own licenses” rather than “through the current sequential process consisting of an FCC auction followed by post-auction negotiations with incumbents.…” (p. 2). In their design of a combinatorial clock auction[1] that would allow buyers to submit bids for packages of items subject to any number of conditions, Porter, et al. (2003, p. 11153) note that any "buyer's auction becomes two-sided when sellers may participate as buyers of their own offerings." Also, Ausebel, et al. (2005) offer a one-sided clock-proxy auction for FCC spectra licenses and observe that this design could be made two-sided by allowing incumbent sellers to bid "negative quantities," which amounts to allowing sellers to express demand for their own licenses.

One of the benefits of Kwerel and Williams' proposal is that it requires few changes to the current allocation process. Yet a key assumption in such a policy proposal is that sellers will not behave differently when framed as buying back their own units in a way that significantly affects efficiency. If sellers behave more or less strategically under alternative frames then this must be considered when determining the final auction design.

Also of interest when designing a two-sided clock auction is the question of the "clock direction." The price may begin low and ascend over the course of the auction, or it may begin high and descend. When both sides of the market share a single clock, then an ascending price simultaneously presents worsening terms of trade ("English") to buyers and improving terms of trade ("Dutch") to sellers. Conversely, a descending price presents buyers with improving terms and sellers with worsening terms. McCabe, Rassenti and Smith (1992) present evidence that in clock auctions worsening or improving terms of trade impact trader behavior. We therefore incorporate clock direction as a treatment variable in our study of frames.

2. The Experimental Design

[1] In a clock auction traders declare the quantity they wish to buy (sell) at prices controlled by a "clock" or the auctioneer.

Our experimental design focuses on clock auctions, in which prices are controlled by a ‘clock’ or auctioneer and bidders have a binary (exit or entry) control over the quantity demanded (supplied) at each price. A form of the clock auction is currently used to sell FCC spectra licenses and is a common feature of the designs proposed by Kwerel and Williams, Porter, et al. and Ausebel, et al. The limited message space provided by a clock auction is also useful in isolating framing effects. Since we are interested in how framing might affect strategic behavior, such as demand or supply reduction, our environment includes large and small traders in an environment with significant strategic uncertainty.

2.1 Description of the Institutions

We use a 2X2 design to isolate the effects of clock direction (ascending or descending prices) and what we shall refer to as “pre-commitment” and “post-commitment” supply rules, referring to the frame on sellers. Under a pre-commitment rule, sellers commit *ex ante* to supply all of their units but are allowed to demand their own offerings, thus ultimately supplying only those items not “won” in competition with buyers. The post-commitment rule does not require sellers to commit an *ex ante* supply and thereby allows sellers to supply units more directly (rather than indirectly by reducing demand for their own offerings). The naming convention for the experimental treatments is displayed in Table 1. We conducted four sessions under each pre-commitment condition and three sessions under each post-commitment condition. All sessions consisted of 15 periods, but the data from four of the APRE periods were lost, leaving a total of 206 data points.

[Insert Table 1 about here]

Each institution, whether adjusting the supply rule or clock direction, represents a combination of treatment variables that should not systematically affect behavior or allocative efficiency. The pre-commitment rule is a frame on sellers and should not, in theory, alter supply decisions. Regarding changes in the clock direction, buyers' and sellers' responses to the terms of trade should be symmetrical, rendering clock direction neutral to overall efficiency. We describe the institutions in turn, beginning with the ascending clock institutions.

2.1.1 *Ascending Pre-Commitment* (APRE)

The APRE institution mirrors a one-sided ascending auction that allows sellers to bid for their own offerings. The auction proceeds as follows. Sellers pre-commit a fixed quantity, which is the maximum supply to be offered at any price.[2] At the initial clock price, which starts low, buyers express full demand for the units on their demand schedules and sellers express full 'demand' for their own pre-committed supply (expressing an unwillingness to sell). The excess demand equals the total demand from buyers and sellers less the pre-committed supply.[3] The price ascends by predetermined increments. Any trader can stop the ascending price at any time, in any order, to reduce her demand by one unit. In the case of sellers, a "reduction of demand" is a commitment to supply one unit at a price greater than or equal to the current clock price. The process of single-unit demand reductions continues until the excess demand falls to zero at which point no further reductions are accepted. The auction is closed and the pre-committed supply is allocated across buyers and sellers at a uniform closing price where supply equals demand. Specifically, the contracts are formed between sellers who reduced demand for their own items and buyers who did not reduce demand.

2.1.2 *Ascending Post-Commitment* (APOST)

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[2] In our experiments, sellers began by pre-committing all of the units provided on their supply schedules.

[3] Notice that the demand sellers have for their own units to begin the APRE treatment exactly offsets their pre-committed supply. Excess demand equals the demand from buyers at the initial clock price.

APOST follows the same process as APRE but removes the pre-commitment rule (the buyer frame) from sellers. Therefore, the first step of APRE, a pre-committed supply, is eliminated. At the initial clock price, which again starts low, buyers express full demand for the units on their demand schedules while the supply starts at zero. The price ascends by predetermined increments. Any trader, in any order, can stop the price to either reduce demand or *add to* supply by one unit. Notice, the incentives for sellers are unchanged, since a reduction in demand in APRE is equivalent to an addition to supply in APOST. Each seller's addition to supply is a commitment to sell one unit at the current clock price or higher. The process of single-unit demand reductions and single-unit supply additions continues until a price is reached at which the excess demand is eliminated. No further reductions or additions are accepted. All pending commitments transact at this closing price where supply equals demand.

2.1.3 *Descending Pre-Commitment* (DPRE)

DPRE is a descending price version of APRE, again involving pre-commitment. Sellers pre-commit a fixed quantity, which is the maximum supply to be offered at the most favorable price. At this initial price, buyers express zero demand for the units on their demand schedules and sellers express zero 'demand' for their own pre-committed supply (indicating a willingness to sell all units). The price descends by predetermined decrements (equal in magnitude to the increments in APRE). Any trader can stop the descending price to express demand for one unit. A seller who expresses demand reduces his or her supply commitments by one unit, also reducing the excess supply by one unit. A buyer who expresses demand is committing to purchase one unit at the current clock price or lower. The process of single-unit additions to demand (from buyers or sellers) continues until the excess supply is eliminated, at which point no further additions are accepted. All transactions occur at the closing price where supply equals demand.

2.1.4 *Descending Post-Commitment* (DPOST)

DPOST removes the pre-commitment stage from DPRE. At the starting price, buyers express zero demand and sellers express a willingness to supply all units on their supply schedules. The price again descends by predetermined decrements. Any trader can stop the descending price to either express demand for one unit or reduce supply by one unit. The process of single-unit additions in demand and reductions in supply continues until the excess supply is eliminated; thereafter, no further reductions or additions are accepted. All transactions occur at the closing price where supply and demand equate.

2.2 Description of the Market Environment

We replicate a stochastic experimental environment used by McCabe, Rassenti, and Smith (1992) (hereafter "MRS") in their study of two-sided clock auctions.[4] Replicating this environment offers several advantages: First, one of the MRS treatments, "Dutch-English (DE)," involved a single descending clock, which offered improving terms of trade for buyers and worsening terms for sellers. DE closely resembles our DPOST institution and therefore provides an opportunity for replication.[5] Second, our APOST closely resembles a hypothetical "English-Dutch (ED)" auction, which MRS did not conduct. Thus, our experiments are an opportunity to

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[4] MRS employ two environments, referred to as E1 and E2. We replicate environment E2.

[5] DE and DPOST differed in three ways. First, in DE, MRS began by asking sellers to indicate the maximum quantity they would be willing to sell at the initial price announcement. At the start of a DPOST auction sellers offered to sell all of the units on their supply schedules by default, but they were allowed to begin reducing units from the first price announcement. Second, the DE instructions involved market language, while DPOST avoided market language, referring to sellers and buyers as "type 1's" and "type 2's" and buying and selling as "transferring" and "receiving." Finally, DPOST enforced anonymity between buyers and sellers, whereas under DE buyers and sellers were identifiable.

“fill in” this missing treatment cell. Finally, the MRS environment includes both large and small traders positioned symmetrically on both sides of the market with a wide competitive equilibrium (CE) price tunnel (accounting for 37.5% of the total available surplus). This structure captures our interest in how framing might influence strategic behavior, such as demand and supply reduction, which could transfer significant gains to either buyers or sellers. Figure 1 shows the experimental parameters of buyers and sellers with the midpoint of the competitive equilibrium normalized to zero.

[Insert Figure 1 about here]

On the demand side, three "large" traders (buyers B1, B3 and B5) are induced with constant marginal values for up to 6 units and two "small" traders (B2 and B4) have constant marginal values for up to 3 units. Similarly, three sellers (S1, S3 and S5) are induced with costs for 6 units and two sellers (S2 and S4) with costs for up to 3 units. The available gains from trade equal $9.60.

To help maintain strategic uncertainty in the environment through iterations of the institution a random constant was added to (or subtracted from) each trader’s value or cost each period, causing the equilibrium prices to randomly shift. Figure 2 shows the midpoint of the CE price tunnel each period ranging from 250 to 600 cents. (Henceforth, when we refer to the CE price, it shall refer to the midpoint of the price tunnel.)

[Insert Figure 2 about here]

In addition, buyers and sellers were rotated along their respective demand and supply curves. At the conclusion of 15 rounds, each trader participated in each of the five buyer (seller) roles 3 times. In addition to maintaining uncertainty, this rotation served to equate the subjects’ expected earnings. Since traders were not aware of the demand and supply structure, these procedures made it difficult to infer market-clearing prices based on information in the current or previous periods, essentially making the environment stochastic.

Procedures

Upon arrival to the experiment, subjects were seated in a classroom setting and provided a written set of instructions as well as a walk-through example of how the auction would proceed.[6] The use of market language was avoided. Sellers were referred to as type 1's, buyers as type 2's. Rather than buying and selling, traders were told that they would be receiving and transferring units. The auction was referred to as a process for transferring units from type 1's to type 2's.

After the instructions, the subjects were called in alphabetical order of first name into a 28-seat computer laboratory with 4 rows of stations. The size of the lab, combined with dividers at each seat, allowed us to provide all traders with anonymity. From their seats, traders could not see each other or the auctioneer, though the auctioneer would be able to see a trader silently raise an ID card above her divider.

Once seated, the experimenter provided traders with an accounting sheet that included their demand (supply) schedule for a practice iteration of the auction. This initial accounting sheet also informed the subject of her type which would remain constant throughout the experiment. Following each auction, each trader was given a feedback ticket indicating the units she received or transferred as well as a new accounting sheet with her values (costs) for the following period.

[6] The instructions and example used are available from the authors upon request

Prices were announced orally and an Excel spreadsheet[7] was used to record reductions or additions at each price. At the start of the period prices changed in increments of 10 cents. Once excess demand (supply) fell to 10 units, the price increment was decreased to five cents. The traders' ID cards served as the sole 'input' for decision-making. To recognize a reduction (addition) the auctioneer would call out the trader's ID number (in first-come, first-served order), then announce the current excess demand or supply, and finally repeat the current price to allow for further reductions from the same trader or others. ID numbers were in no way correlated to a trader's type as a buyer or seller.

Regarding the pre-commitment and post-commitment supply rules, note that a type 1 trader (seller) who raised an ID card was adding to the supply under either rule. For example, under APRE a seller who raised an ID card was reducing the number of pre-committed units she wanted to "receive" (and thereby increasing the number she wanted to sell) whereas under APOST the seller was directly adding to the number of units she wanted to "transfer." Likewise, with descending prices, a seller who raised an ID card was always reducing supply, either by receiving (not selling) a pre-committed unit DPRE or reducing the number of units the seller was willing to transfer in DPOST.

Traders were unaware of the number of auctions that would be conducted, though they were promised not to be kept for more than 2 hours. The average experiment (consisting of 15 auctions in addition to instructions and a practice period) lasted approximately 90 minutes. At the conclusion of the experiment, traders were called one at a time by ID number to a payment window to receive their cash earnings in private and exit the experiment. In addition to a $7 participation bonus, the average trader earned $21.56 in gains from exchange.

[7] The spreadsheet format is available upon request.

3. Results

The experimental treatments--APRE, APOST, DPRE and DPOST—differ with respect to supply frame and clock direction. We take as our null hypothesis that outcomes are statistically equivalent across treatments. To test for framing and (or) clock direction effects we specify the following random-effects regression model:

$$y_{it} = \alpha + \beta_1 DESCEND + \beta_2 PRECOM + \beta_3 t + \mu_i + \varepsilon_{it}$$

Where y_{it} is the dependent variable of interest in period t of session i,[8] *DESCEND* and *PRECOM* are dummy variables indicating a descending clock price and pre-commitment rule respectively, and the μ_i are random effects assumed to be $\sim N(0, \sigma^2)$. The error term is corrected for an AR(1) process, and data from the first five periods were omitted to focus the analysis on relatively experienced traders.

3.1 Strategic Reduction

One concern in one-sided clock auctions for multiple units is "demand reduction" which occurs when buyers reduce demand at prices below value in an effort to stop an ascending clock.[9] Demand reduction is a profitable strategy for an individual buyer if the uniform price on the units he purchases is low enough to offset the losses of foregone transactions. The same

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[8] In the case of strategic reduction *i* indexes the subject rather than the session.

[9] For a theoretical model showing that all uniform price multiple-unit auctions encourage demand reduction, see Ausubel and Cramton (2002). For evidence of demand reduction in laboratory experiments, see Alsemgeest, Noussair and Olson (1998), Porter and Vragov (2006) and Kagel and Levin (2001). For evidence of demand reduction in multiple-unit field experiments, see Engelbrecht-Wiggans, List and Reilly (2006) and List and Lucking-Reilly (2000).

logic can be used to justify supply reduction on the part of sellers in an effort to increase price. We measure strategic reduction, for buyers, as the percentage of units reduced at prices below value or, for sellers, at prices above cost. Note that the side of the market facing a favorable clock direction (buyers facing a descending price or sellers facing an ascending price) can only add to demand or supply, so for these traders we measure reductions by the percentage of units not demanded or supplied at closing prices below value or above cost. More formally, for traders facing worsening terms of trade, the strategic reduction of trader i in period t, ρ_{it}, can be expressed as:

$$\rho_{it} = \frac{\sum_{j=c}^{v_{it}-k} \delta_{ijt}}{U_{it}}$$

Where:

δ_{ijt} is the number of units dropped by trader i at clock price j in period t

c is the initial clock price

k is the price increment if i is a buyer, and the price decrement otherwise

v_{it} is the value (cost) of a unit induced on trader i in period t

U_{it} is the total number of units on the demand (supply) schedule of trader i in period t

This measure of demand reduction (in response to worsening terms of trade) can be illustrated by a simple example. Suppose that in the APRE (or APOST) treatment a subject, B1, is induced with a constant marginal value of 100 cents for up to 6 units of which she drops 3 units at the initial price of zero, and the remaining 3 at the price of 100 cents where any potential contracts would no longer be profitable. Demand reduction for B1 equals 50%. Only the units dropped below value are considered "strategic." If the buyer had reduced all 6 units at the price of 100 cents, strategic reduction would be 0%.

A seller in the ascending clock treatments and a buyer in the descending clock treatments faces improving terms of trade and can only add to the supply or demand, so strategic supply reduction is based on the final closing prices. For traders facing improving terms of trade, the strategic reduction of trader i in period t, ρ_{it}, can be expressed as:

$$\rho_{it} = \frac{U_{it} - U_{it}^{T}}{U_{it}}$$

Where:

U_{it} is the total number of units on the demand (supply) schedule of trader i in period t

U_{it}^{T} is the number of units transacted by subject i in period t

For example, if a seller with a constant marginal cost of 90 cents for up to 3 units supplies 2 units at a price of 110 cents, after which the auction closes at 130 cents, the seller's supply reduction is 33.33% indicating that the seller did not supply 1 of 3 units for which the closing price exceeded the seller's cost. In analyzing strategic reduction for traders facing improving terms of trade, we omit instances where the final closing price failed to reach a profitable threshold either above a sellers cost (or in descending treatments, below a buyers value). This is consistent with our only counting potentially profitable reductions as strategic for traders facing worsening terms of trade. Table 2 displays the estimates from separately fitting the strategic reduction behavior of buyers and sellers to our regression model. These estimates show three significant findings:

3.1.1 *Buyers behaved more strategically than sellers*.

Evaluating behavior across all treatments, we find that whether a trader was in a buyer or seller role was a strong determinant of strategic reduction. The estimated constant in the buyer regression is 0.372 ($p < 0.001$), indicating a baseline rate of reduction of 37.2% among buyers, or slightly more than 2 of 6 units for large buyers and 1 of 3 units for small buyers. Sellers' baseline rate of reduction, at 16.6% ($p < 0.001$), was less than half that of the buyers. This asymmetry diminished slowly with experience. While seller reductions remained constant, buyer reductions fell by 0.7 percentage points per round ($p = 0.024$), suggesting the possibility of an eventual convergence. Nevertheless, by period 15 buyers reduced an estimated 26.7% of their units, approximately 60% more than reduction among sellers.

This asymmetry has precedence in the literature. For instance, research on double auctions have demonstrated a small but persistent asymmetry in favor of buyers in the division of available surplus, suggesting that the average buyer is a more resolute negotiator than the average seller (see Smith and Williams 1982). Behavior in our experiments was analogous in that buyers were, on average, more active in attempting to manipulate price.

3.1.2 *Demand reduction was sensitive to clock direction; supply reduction was not*.

Consistent with MRS, we find that buyers behave more strategically when facing worsening terms of trade (an ascending clock) than improving terms (a descending clock). However, we find did not this effect for sellers. Figure 3 displays the strategic reduction averaged across sessions among buyers. After period four, buyers' average strategic reduction was higher in the ascending treatments, APRE and APOST, without exception. Figure 4 depicts supply reduction among sellers. Holding the supply frame constant, sellers maintain the same level of reduction irrespective of clock direction.

[Insert Figures 3 & 4 about here]

These results are confirmed by the statistical analysis (see Table 2). The effect of clock direction was pronounced for buyers. Under the descending clock rule, buyer reductions fell by 19.5 percentage points ($p < 0.001$), a decrease of more than half of the baseline. For sellers, the descending clock price was not correlated with reduction. The dummy variable, DESCEND, is estimated to be positive, suggesting that sellers reduced more under worsening terms of trade, but the result is not statistically significant ($p = 0.161$).

The asymmetry implies that the descending clock institutions (DPOST and DPRE) generate less overall strategic reduction than the ascending treatments by limiting demand reduction, while not encouraging more supply reduction.

3.1.3 *Supply reduction was sensitive to the commitment rule*

Although sellers were not sensitive to clock direction, the pre-commitment rule increased supply reduction by almost 8 percentage points ($p = 0.025$) (see Table 2). In the ascending treatments, average supply reduction was higher in APRE than in APOST in every period (see Figure 4). Similarly, in the descending treatments, DPRE generated more supply reduction on average than DPOST in 12 of 15 periods. Given that the supply rule only frames the seller side of the market, we were not surprised to find that buyers were insensitive to the supply rule.

That a pre-commitment rule generates more strategic behavior among sellers demonstrates that the difference we find in baseline strategic behavior between buyers and sellers extends also to sellers who are put in the context of buying their own offerings. Just as buyers reduce demand more than sellers, sellers who make supply decisions by buying back their own offerings also behave more strategically than sellers who make supply decisions directly.

3.2 Efficiency

We measure efficiency as the surplus realized by traders over the available surplus in the environment. Strategic reduction and efficiency are interrelated, since quantities reduced at prices below value or above cost either reduce the quantity traded or generate transactions with extra-marginal traders with lower values (or higher costs), thereby reducing the realized gains from trade. At the CE allocation, only two traders, Buyer 5 and Seller 5, can reduce. All other reductions lower efficiency.

From our analysis above we know that an ascending clock rule and a pre-commitment supply rule encourage strategic reduction, and that the clock direction dominates the supply rule. One would expect the efficiency ranking of the four institutions (in order of highest to lowest) to be: DPOST, DPRE, APOST, APRE. This prediction is confirmed by the data. Figure 5 displays the average efficiency by period for each treatment.

[Insert Figure 5 about here]

After the first 5 periods the institutions show a clear separation in which the descending clock dominates an ascending clock, which is in line with our finding that buyers (but not sellers) were sensitive to clock direction and behaved less strategically when the price was moving in a favorable direction. Likewise, the post-commitment supply rule on sellers dominates pre-commitment. DPOST is the most efficient institution because, in addition to reducing strategic behavior from buyers with a favorable descending price, DPOST reduces strategic behavior from sellers with the post-commitment supply rule. By removing both of these efficiency-enhancing rules, APRE underperforms all other treatments. APRE encourages buyers to reduce more in response to worsening terms of trade, and sellers to reduce more in response to the pre-commitment rule. The DPRE and APOST institutions, which have only one of these framing effects, fall in the middle.

Fitting the efficiency data to our regression model confirms that a descending clock increased efficiency by 8.6 percentage points ($p < 0.001$), or 12.7% above the baseline estimate of 67.8% efficiency (see Table 3). The framing effect from the pre-commitment rule reduced efficiency by 5.5 percentage points ($p = 0.005$), which is equivalent to an 8.1% loss as compared to the baseline.

All four treatments showed learning over time. With experience, the average efficiency increased by 1.1 percentage points per period ($p < 0.001$). Our model estimates efficiencies in the final auctions of the four treatments to be 78.7% (APRE), 84.2% (APOST), 87.3% (DPRE) and 92.8% (DPOST). Thus, even with experienced traders, we would expect the supply frame and clock direction to have a significant impact.

As noted in Section 2, our DPOST treatment is an approximate replication of a two-sided descending auction conducted by MRS. They also report efficiencies on two other institutions which used separate clocks for buyers and sellers to simultaneously provide worsening or improving terms of trade to both sides of the market, also called Double-English (EE) and Double-Dutch (DD) auctions. Having replicated the environment used in MRS, we use their results to validate our findings with respect to clock direction.

MRS report that improving terms of trade for both sides of the market (DD) achieved efficiencies of 98% while worsening terms of trade (EE) achieved less than 80% of the available gains from trade. Their descending single clock institution DE (a close approximation of our DPOST treatment) achieved 94% efficiency. MRS hypothesized that worsening terms of trade encouraged strategic reduction; however, we find that this applies only to buyers and not sellers.

(MRS report efficiencies, but not reductions.) If our finding on the asymmetric effect of clock direction is valid, we would expect MRS's DE treatment and our DPOST treatment to achieve efficiencies closer to the all-improving case (DD) than to the all-worsening case (EE), because DE presents worsening terms of trade only to sellers, who do not respond to clock direction. Similarly, we would expect our APOST treatment (of which MRS has no counterpart) to achieve efficiencies closer to EE, because our claim is that buyers are behaving more strategically in both cases responding (as MRS predict) to worsening terms of trade.

[Insert Figure 6 about here]

Our expectations are born out in the data. Figure 6 displays average efficiency in the last five rounds of the DD, DE, DPOST, APOST, and EE treatments.[10] As noted above, MRS's DE achieved roughly 94% efficiency, which is much closer to DD than EE. Our APOST treatment's average efficiency was slightly less than 81%, closer to EE than DD. The DPOST treatment's average efficiency was somewhat lower than DE, at 89.4%. That our DPOST achieves slightly lower efficiencies than DE may be due to the differences in experimental protocols between the two treatments. Specifically, MRS's use of market language may have clarified the institution to their subjects, resulting in higher efficiencies. The difference could also be explained by subtle differences between the auctioneers (also a frame). Overall, we consider the DPOST institution to be a successful replication of the DE auction.[11]

3.3 Price

[10] Efficiencies for the DD, DE and EE treatments are taken from Figure 6 (a) in MRS.

[11] Unfortunately the round-level data are not available from the MRS experiments, so a statistical comparison of the two treatments is not possible.

All of the institutions studied generated prices within the CE price tunnel, despite efficiencies lagging from strategic reductions. Figure 7 displays the average deviation from the midpoint of the price tunnel across sessions for all four institutions.[12] With the exception of the APRE treatment, the average price across sessions was within the CE tunnel from the first period onward, and in no treatment were prices systematically inconsistent with the CE prediction. Average prices fell within the CE price tunnel in 83.4% of all periods (172 out of 206).

[Insert Figure 7 about here]

Within this general conformity to the CE, however, prices remained sensitive to clock direction. Ascending clock auctions tended to generate prices 5-10 cents below the midpoint of the CE price tunnel, while descending clock auctions tended to generate prices 5-10 cents above the midpoint. Holding clock direction constant, the pre-commitment rule tended to generate prices slightly higher than post-commitment.

These results are in line with our analysis of strategic behavior. As a rule, prices will tend to favor the more actively strategic side of the market. Given that buyers behaved more strategically when facing worsening terms of trade, but seller behavior was unaffected by clock direction, we would expect more downward pressure was exerted on the price under an ascending clock than a descending clock. Similarly, sellers were more strategic under a pre-commitment rule, while buyers did not respond to the supply frame. As a result, the pre-commitment rule produced more upward pressure on the price than the post-commitment rule.

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[12] Recall from Figure 1 that the price tunnel spans 20 cents, so taken from the midpoint of the tunnel a price in the interval [-10, 10] is consistent with the competitive equilibrium.

To test these hypotheses statistically we use deviation from the mid-point of the CE price tunnel as the dependent variable in our regression model (see Table 4). The estimated constant term indicates that prices tended to be seven cents below the mid-point of the price tunnel in the ascending clock auctions ($p = 0.033$). The descending clock rule is estimated to increase price by 8.8 cents ($p < 0.001$), a substantial effect, as it equates to 44% of the price tunnel, or 16.5% of the available surplus in our experimental environment.

The estimated effect of the pre-commitment rule is positive but small in magnitude and falls short of conventional significance levels (p = 0.111). Thus, while we have confidence that the pre-commitment rule induces more strategic reduction from sellers, we cannot be confident that the effect is sufficient to influence closing prices.

4. Discussion

These results on framing effects in two-sided clock auctions highlight the role of auction design not only in mapping messages into allocations but also in presenting the message space to traders, which may have a significant impact on the realized gains from trade. We find that sellers able to buy their own offerings in a clock auction (selling the items not "won") are likely to behave more strategically than sellers who supply units directly. Furthermore, these post-commitment and pre-commitment supply frames have more influence on how strategically sellers behave than the direction of clock prices, which would seem to be a more fundamental design decision.

Given that sellers behave more strategically when under a pre-commitment supply rule, practitioners ought to proceed with caution when implementing a proposal to have sellers bid on their own offerings. Where possible, a direct supply rule is preferred. In our environment, the efficiency cost of the pre-commitment rule was 5.5%. Therefore, the move from a one-sided auction to an equivalent two-sided auction in which sellers bid on their own offerings must be associated with an efficiency gain of at least 5.5% to justify making a one-sided auction two-sided in this manner. The comparative performance of one-sided versus two-sided auctions is an empirical question deserving of investigation.

We also find that buyers behave more strategically than sellers in clock auctions, but demand reduction can be significantly reduced by presenting buyers with improving terms of trade through a descending clock. Sellers behave less strategically regardless of clock direction. The asymmetrical effect allows the two-sided descending price auction (DE and DPOST) to encourage more truthful demand revelation from buyers with no corresponding increase in supply reduction.

Finally, our results demonstrate that in designing auctions, substantive changes to the message space may be as important to outcomes as more traditional auction rules. With just two institutional changes, both inconsequential to the traders' incentives, the estimated final round efficiencies increased by more than 14 percentage points between the APRE and DPOST treatments. This result suggests a clear role for framing as an additional tool in auction design.

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Figures and Tables

Figure 1. Supply and demand environment -- values and costs are normalized with the midpoint of the competitive equilibrium equal to zero.

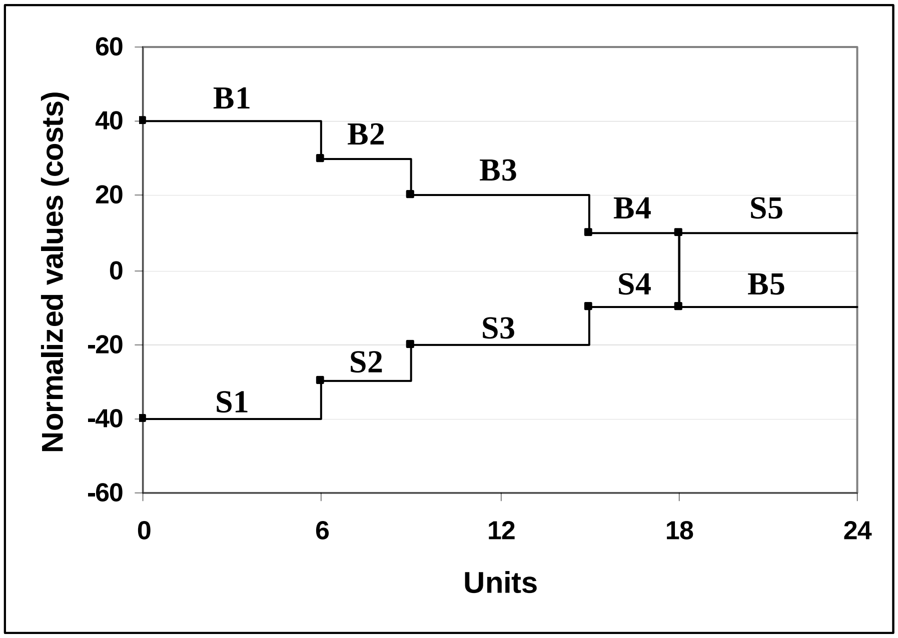

Figure 2. Midpoint competitive equilibrium prices for periods 1 – 15.

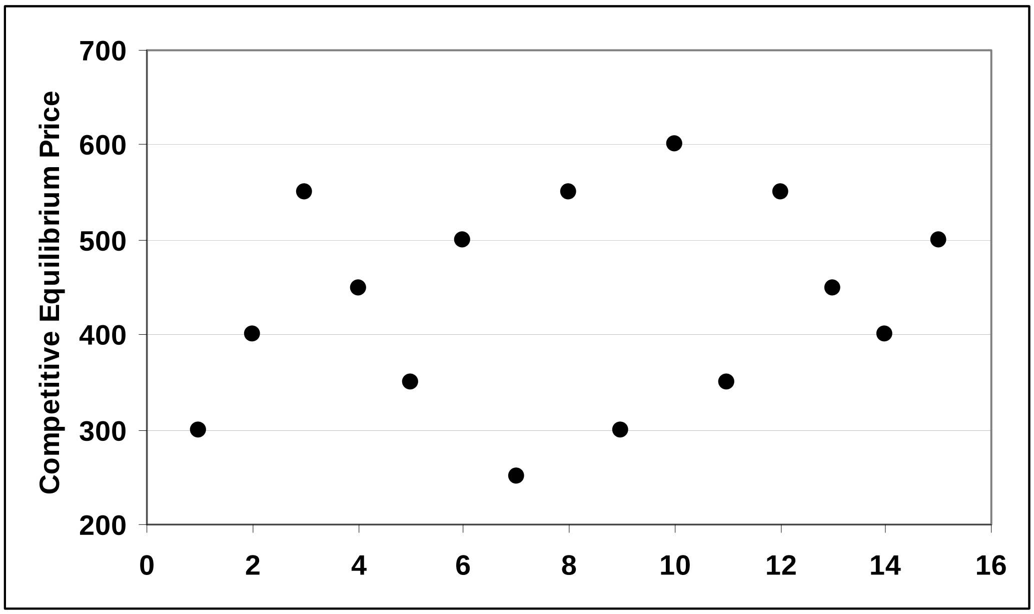

Figure 3. Average demand reduction by period (averaged across sessions).

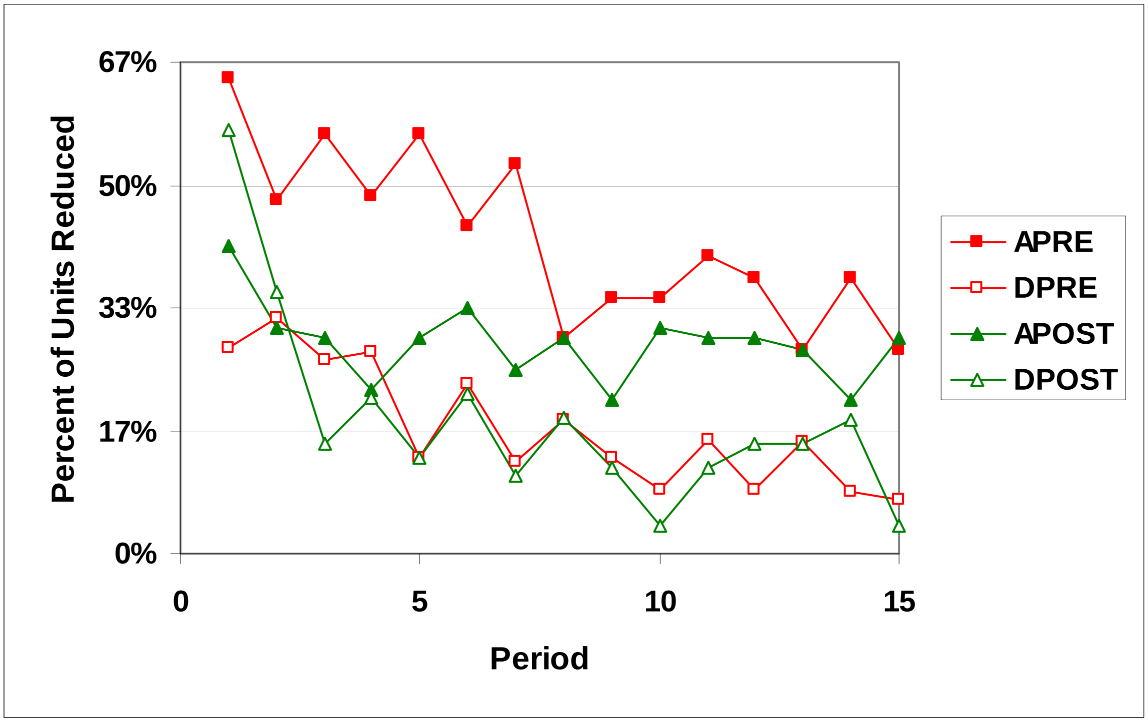

Figure 4. Average supply reduction by period (averaged across sessions).

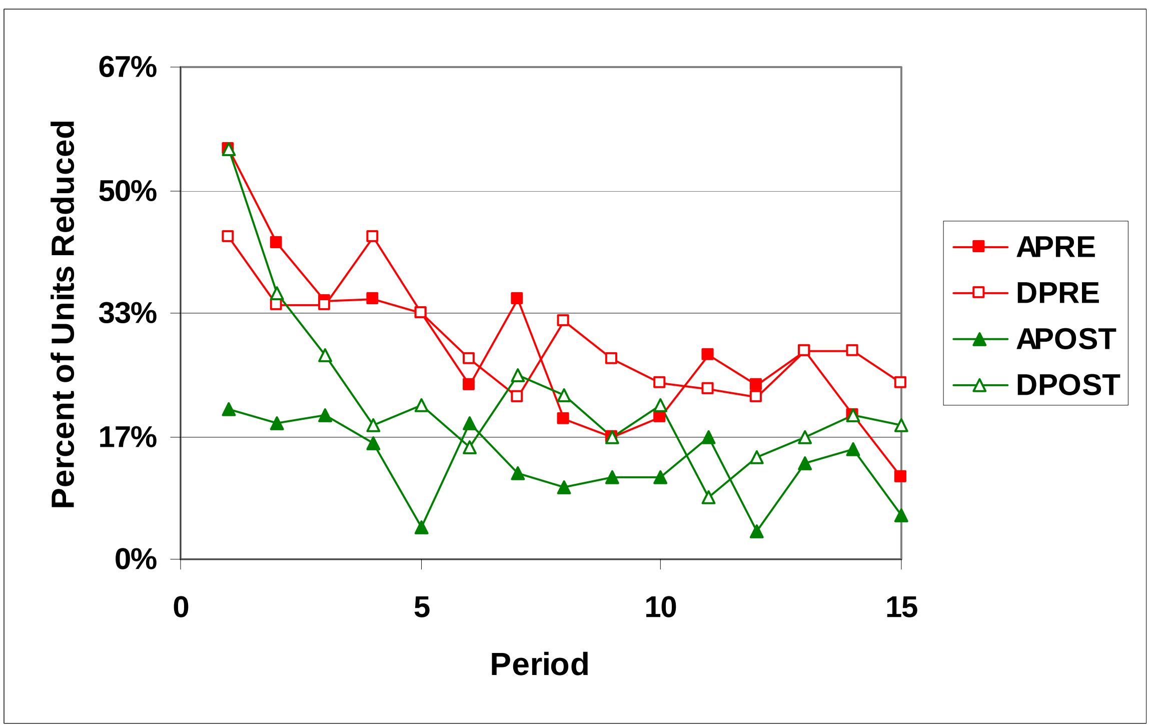

Figure 5. Average efficiency by treatment

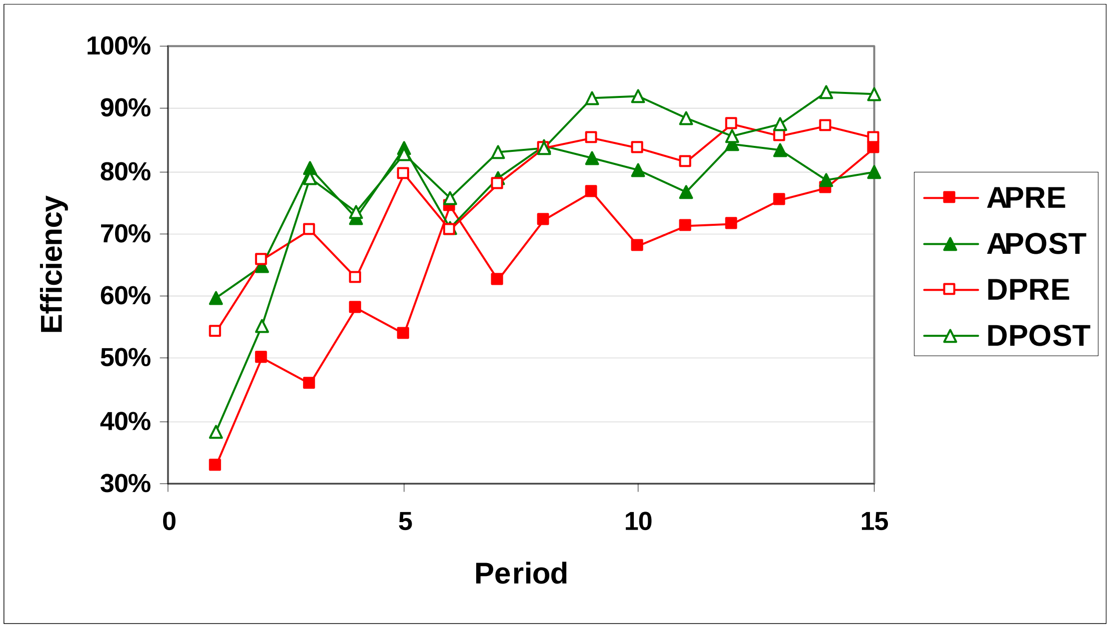

Figure 6. Average efficiency in last five periods – DD, DE, DPOST, APOST and EE institutions (replicated MRS treatment in parentheses)

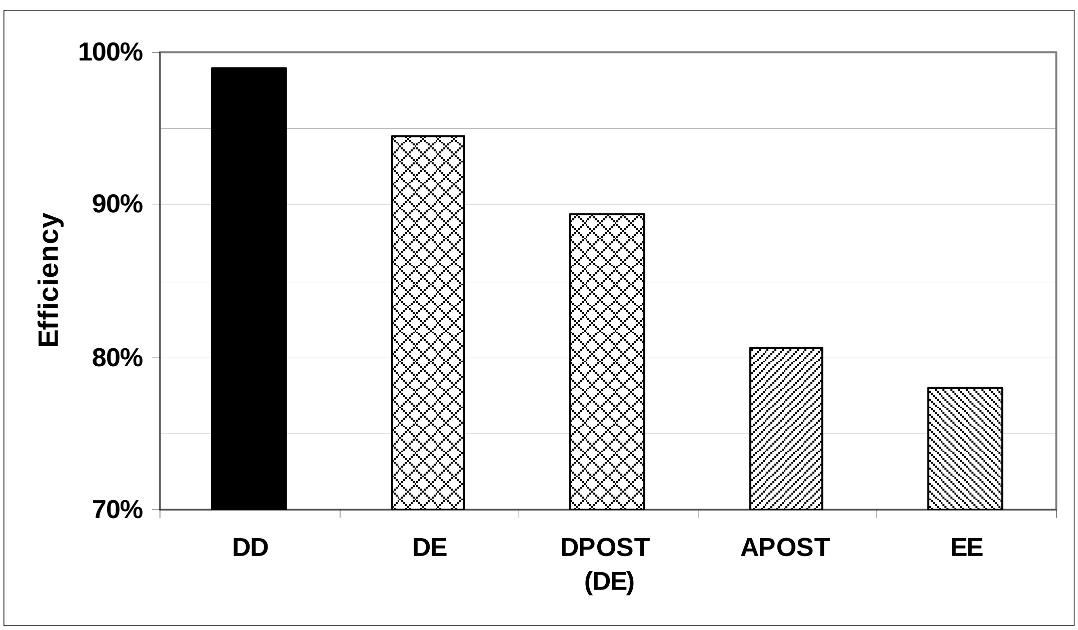

Figure 7. Average deviation from the CE price (in cents) – CE midpoint normalized to zero

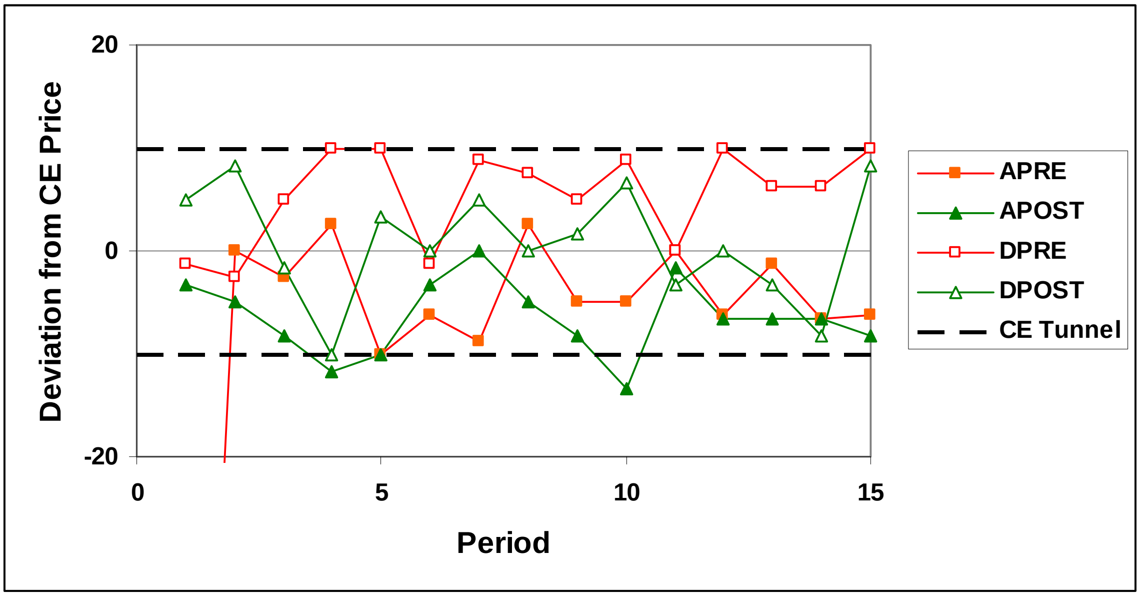

Table 1. Treatment Design (number of sessions in parentheses; 15 periods per session)

		Supply Rule	
		Pre-Commitment	Post-Commitment
Clock Direction	Ascending	APRE (4)	APOST (3)
	Descending	DPRE (4)	DPOST (3)

Table 2. Estimates from regression analysis of subject-level strategic reduction

Variable	Coefficient (Std. Error)	
	Buyers	Sellers
α	0.372** (0.053)	0.166** (0.048)
Descend	-0.195** (0.046)	0.05 (0.035)
PreCom	0.043 (0.046)	0.079* (0.035)
t	-0.007* (0.003)	-0.004 (0.003)
Obs:	579	582
R^2:	0.1282	0.0385

* Significant at 5% confidence level

** Significant at 1% confidence level

Table 3. Estimates from regression analysis of efficiency

Variable		Coefficient (Std. Error)	
α		0.678** (0.034)	
Descend		0.086** (0.019)	
PreCom		-0.055** (0.02)	
t		0.011** (0.003)	
Obs:	140	R^2:	0.2979

* Significant at 5% confidence level

** Significant at 1% confidence level

Table 4. Estimates from regression analysis of deviation from the competitive equilibrium price

Variable		Coefficient (Std. Error)	
α		-7.05* (3.314)	
Descend		8.8** (2.027)	
PreCom		3.26 (2.048)	
t		0.01 (0.265)	
Obs:	140	R^2:	0.2602

* Significant at 5% confidence level

** Significant at 1% confidence level